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SPECTRAL EVIDENCE OF OUTFLOW OF MOLECULAR HYDROGEN IN THE REGION OF ARISTARCHUS

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SPECTRAL EVIDENCE OF OUTFLOW OF MOLECULAR HYDROGEN IN THE REGION OF ARISTARCHUS

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ABSTRACT. Spectral observations of the crater Aristarchus during November and December 1961 showed a comparatively stable outflow of gas near its center. The emission band 4634 ± 1 Å with a sharp red border and weak emission in the orange-red spectral region were detected.

These data are evidence that there was an outflow of molecular hydrogen of the fumarole type of Earth volcanoes.

In order to clarify the luminescence glow of the Moon in 1955, a photometric comparison was made of the spectra of different objects on the lunar surface and the solar spectrum [1]. The spectrograms were obtained on a 50-inch reflector of the Crimean Astrophysical Observatory, using a spectrograph having a linear dispersion of about 23 Å at 1 mm near H_γ. Particular attention was devoted to comparing the contours of the wide lines of the doublet Ca^+ H and K in the spectra of objects on the lunar surface and in the solar spectrum. There was a significant difference in the contours of these lines and the contours of the solar spectrum only in the spectrum of the Aristarchus crater. In the Aristarchus spectrum, the lines were narrower than in the solar spectrum. It thus follows that there is a luminescence glow in the Aristarchus crater which closes the line contours. A photometric study showed that this glow exists in the narrow wave portion of the spectrum at $\lambda < 4000$ Å. In addition, there was a second, weaker region of luminescence between 4400 and 4100 Å. /99*

*Numbers in the margin designate pagination in original foreign text.

This luminescence of the Aristarchus crater was most clearly apparent after a full Moon. However, at the same phase but in different months, the luminescence brightness was far from the same. These fluctuations in brightness had no connection with solar activity. Therefore, the question arises of whether they can not be explained by changes in the activity of the crater itself. Such an explanation may be valid, if a significant portion of the observed emissions is caused, not by luminescence of solid rocks, but by luminescence of gas outflows from the Aristarchus crater. In order to study this problem, in November-December, 1961, a new series of spectral observations of the Aristarchus crater was performed on a 50-inch reflector of the Crimean Observatory.

In 1961, spectra of the Aristarchus crater were obtained on a different spectrograph with a small dispersion, on the order of 150 Å at 1 mm near H_γ. The spectra were recorded with a wide slit, thus making it possible to have the spectrum of the crater and the spectra of its surroundings at the same time. At this time, the photometric processing of the spectra obtained was concluded by comparing the spectrum of the objects studied with the spectrum of the surroundings, and not with the solar spectrum. On November 30, in the morning, the Moon was in the last quarter. Spectrograms of the Aristarchus crater and its surroundings were obtained during the nighttime in November on the following days:

25-26, 27 - 28, 29 -30, and in December:

1 - 2, 2 - 3.

On these nights, a large number of spectrograms were made of details in the Aristarchus and Herodotus craters, the Schroeter Valley, individual craters, and other details of the Wood Spot . A group of emission bands, beginning abruptly and passing further toward the short-wave end of the spectrum, was even noticeable without photometric comparison on certain spectrograms obtained in the very center of the Aristarchus crater, between H_β and H_γ. Figure 1 shows the results derived from photometric processing of spectrograms of this spectral region. The logarithms of the ratios between the brightness of the Aristarchus center spectrum and the brightness used for comparing the spectrum of one of the adjacent details of the lunar surface are plotted along the ordinate axis. Spectrograms for November 25 and 27 were each measured with respect to two different comparison spectra. As may be seen from Figure 1, the emission may be

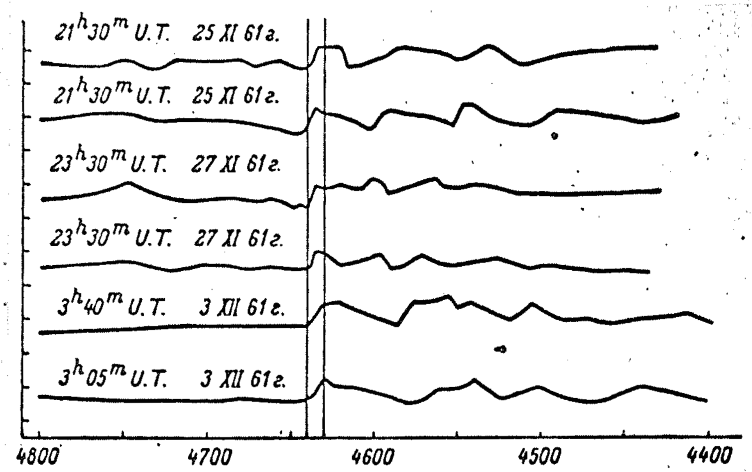

Figure 1. Emission observed in the blue portion of the spectrum for the crater Aristarchus. One division on the vertical scale equals 0.10 of the common logarithm of brightness.

observed on two spectrograms obtained on December 3. The sharp emission boundary near the red end of the spectrum and its clearly marked structure definitely establish the gaseous nature of this emission. Important confirmation of this conclusion is the fact that, in photographs taken December 3, the emission bands observed above the bright central portion of the crater protrude /100 somewhat into the spectrum of the shade thrown out by the Eastern side of the crater edge. It thus follows that the emission source extends to a certain height above the crater surface.

The observations indicate that there is actually liberation of gases in the center of the Aristarchus crater, more precisely, in its central peak. The activity of such processes cannot be constant. It is very possible that the observation of emissions close to the last quarter, i.e., when the Sun is above the crater, is not accidental, and that the outflow of gases is facilitated by heating by solar rays of the corresponding crater regions. It is now interesting to clarify the chemical nature of the gases producing the observed emission.

Figure 1 shows that the sharp emission boundary from the red end of the spectrum has a wavelength between 4630 and 4638 Å. On the average λ = 4634 Å for this boundary. The tables of molecular spectra do not indicate the existence of a band with a red edge of this wavelength. Bands of the molecules AlJ or ZrO are more suitable. However, the behavior of other bands of these molecules completely refute such a possible identification. There is still one other interesting possibility related to the form of the Eastern hydrogen

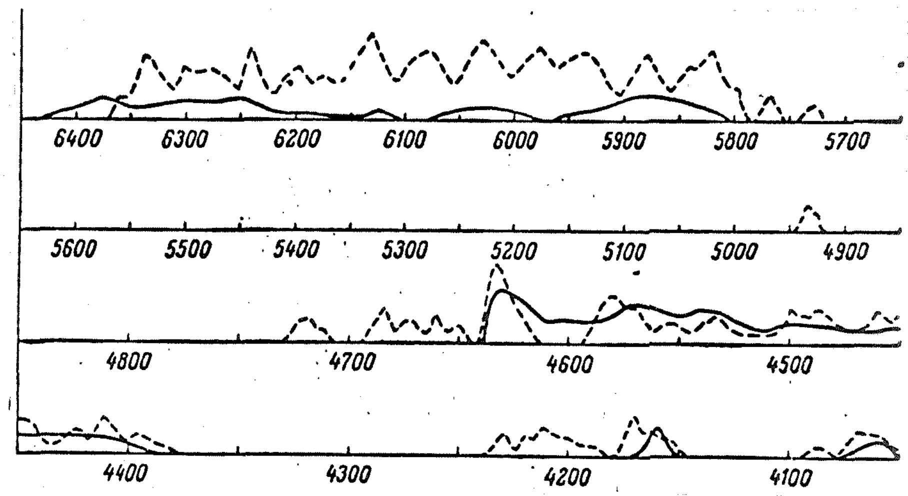

Figure 2. Comparison of emission observed in the Aristarchus crater (solid line) with the emission spectrum of molecular hydrogen obtained with the same dispersion (dashed line, drawn in an arbitrary scale). One division on the vertical scale equals 0.05 of the common brightness logarithm.

spectrum, i.e., the spectrum of the H_2 molecules for small dispersions. The brightest lines of this complex spectrum are concentrated in two wavelength regions — the reddish-orange and the blue. The blue region of H_2 emission begins with a particularly bright line having a wavelength at 4634 Å. This is the main line of the singulet system $3d^1\Sigma \rightarrow 2p^1\Sigma$ of hydrogen vapor. Because of this line, for small dispersions the blue spectral region of H_2 will appear as a wide band with a sharp red edge. For purposes of better comparison in the laboratory, we recorded and measured the H_2 spectrum obtained by a spectrograph, of almost precisely the same dispersion as that used to obtain the spectrum of the Aristarchus crater. The dashed lines in Figure 2 show the results of measuring this laboratory spectrum of H_2. The solid line shows the supplementary emissions of the Aristarchus crater measured over the entire spectrum. In the blue spectral region, this curve is obtained by averaging the data in Figure 1. The dashed and solid lines closely coincide. With respect to the reddish-orange spectral region, where there is intense emission of H_2 molecules (primarily the triplet lines of ortho-hydrogen), photometric measurements reveal a weak glow of the Aristarchus crater.

It is important to note that both these emissions are bounded by approximately the same wavelength region. The lack of agreement between the pattern of the solid line and that of the dashed line must primarily pertain to the small dispersion and the overexposure of photographs in this spectral region. It is our opinion that the material in Figure 2 leads to the reliable conclusion that the gas outflowing from the Aristarchus crater is molecular hydrogen. /101

Usually, the atomic hydrogen spectrum exists along with the secondary hydrogen spectrum under laboratory conditions. In the spectrum of the Aristarchus crater, special measurements did not reveal any differences between the Balmer lines and the Balmer line of the spectrum for its surroundings. Thus, it may be assumed that no significant amount of atomic hydrogen is produced in the excitation of molecular hydrogen outflowing from the center of the Aristarchus crater. This represents a very important characteristic of hydrogen glow processes on the Moon. It must be noted that it is extremely difficult to find a correct explanation for this glow mechanism, due to the large excitation energies of H_2 molecules. The observed outflow of molecular hydrogen cannot be the result of photodissociation of water vapor, since only the formation of H and OH is intrinsic to this process. H_2 can be produced by the photodissociation of other molecules. It must therefore be concluded that molecular hydrogen is produced directly in the interior of the Moon. It can then accumulate there. This conclusion regarding existence of molecular hydrogen in the interior of the Moon agrees with the existence of local accumulations of hydrogen in the Earth's crust. The important role of molecular hydrogen outflow in the volcanic processes on the Earth is well known.

The observations described here show that comparatively stable gas outflows of the fumarole type of our terrestial volcanoes exist on the Moon, in addition to spontaneous volcanic processes observed on November 3, 1958 and October 23, 1959 in the Alfons crater. The fumarole field was located to the east of the central peak in the Aristarchus crater, and was on the order of 1-2" in size, i.e. 2-4 km. Close to this field (on the eastern edge of the Aristarchus crater and at the apex of the Schroeter Valley) Greenacre and Barr at the Lowell Observatory on 30 October 1963 observed two regions which were reddish-orange in color and lasted for 20 minutes [2]. During these observations, the Aristarchus crater was close to the terminator for 2.5 days before the full Moon.* The brief appearance of the bright color is definitely caused by the outflow of gases whose glow was particularly apparent on the background of the lunar surface close to the terminator. The almost simultaneous appearance of gases in two regions separated by 35 km (5 minutes earlier in the Schroeter Valley) could have been the result of a single deep process.* Thus, these new observations of Greenacre and Barr confirm the great volcanic activity of the Aristarchus crater region.*

In conclusion, it must be pointed out that the enigma of the Aristarchus crater has been far from solved by these observations. The question still remains as to what contribution the gas component makes to the total luminescence of the Aristarchus crater. In general, was this luminescence of a solid surface, or was the luminescence discovered in 1955, which closed the contours of the H and K lines, entirely the luminescence of certain gases outflowing from the crater interior which are still unknown?

*Translator's Note: Next line deleted as indicated in original text.

REFERENCES

1. Izvestiya Krymskaya Astrofizicheskaya Observatoriya, Vol. 16, 1956, p. 148.

2. C.D. Bureau, Telegrammes Ast., No. 1847.

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